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Finnish primary school students' perceptions on water systems: Exploring sources and usage at home and in society

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Abstract
Previous studies have shown that making informed decisions about water issues requires socio-scientific reasoning (SSR), which is challenging for primary school students. This study focuses on third and fourth graders' (n=101) perceptions regarding water systems, water sources and usage patterns both at home and within society. The primary school students participated in a water project that lasted for eight lessons. The study was a case study and the data consisted of audio recordings of group conversations on tasks given in the lessons. The students' perceptions were analyzed using inductive content analysis and structure of observed learning outcome-taxonomy. Students discussed the significance of using water for drinking, food preparation, and maintaining personal hygiene. Students highlighted conservation, health, environmental and household aspects when discussing water conservation and water purification. There is a need to empower primary school students through building scientific literacy and SSR to inform evidence-based decisions related to water issues.

Keywords: primary school, socio-scientific issue, water systems, water usage, water purification, scientific literacy, socio-scientific reasoning

INTRODUCTION

Global concern for water issues is increasing, emphasizing the urgent need to educate the next generation about sustainable water usage. This fosters a more informed and engaged behavior among citizens (Koop et al., 2019; March et al., 2014; Meganck, 2010; Sammel, 2014; https://www.unesco.org/en/wwap/wwdr/2020). Primary schools play an important role in raising awareness, imparting knowledge, and promoting positive behavior changes among students, highlighting the importance of clean water, proper sanitation, and water conservation (Amahmid et al., 2019; Khiri et al., 2023). To create this, integrating scientific literacy (SL) during water education programs is important (Mostacedo-Marasovic et al., 2022). By empowering students with SL, they gain the ability to critically evaluate information and actively participate in the sustainable management of natural resources (e.g., Kaya et al., 2012; Smith et al., 2012).

According to Sjöström and Eilks (2018), all SL visions (I-III) influence the content of teaching and learning science. SL vision I focuses principally on learning and teaching scientific concepts and scientific processes (Roberts, 2007; Roberts & Bybee, 2014). In contrast, vision II of SL establishes a link between science and students' everyday experiences, ensures citizens have the empowerment to participate in civic discussions, make informed decisions related to health, nutrition, environment, and technology (Haglund & Hultén, 2017; Kolstø, 2001; Sjöström & Eilks, 2018, p. 65-66). Vision II also includes applying knowledge and functional competence (Holbrook, 2010; Holbrook & Rannikmae, 2009). Nowadays SL (vision III) focuses more on relevance for critical citizenship and sustainability, and it is agency-orientated (Sjöström & Eilks, 2018). In the science education context, there is a growing interest to address major environmental and sustainability challenges, such as water management and protection (Bhat, 2017; Jorgenson et al., 2019; Payne, 2020).

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Contribution to the literature

- Despite the impact of water-related decisions on both personal and societal levels, research in this domain at the primary school level remains relatively sparse.
- This study endeavors to shed light on primary school students' perceptions and socio-scientific reasoning regarding water sources and usage at home and society.
- Findings of this research showed that there is an obvious need to encourage primary school students to connect and synthesize water issues and think about alternative perspectives.

Achieving SL regarding water issues can pose several challenges. Previous studies concerning primary school students' perceptions concerning water issues (e.g., Ben-Zvi Assarf & Orion, 2005; Covitt et al., 2009; Varelas et al., 2006) have revealed students possess an incomplete picture of the phenomena of water or the water cycle. Different ages of students had common misconceptions concerning groundwater (Ben-Zvi Assaraf et al., 2012; Reinfried, 2006), causal structures in ecosystems (Grotzer & Basca, 2003), system thinking in complex relationships within systems (Evagorou et al., 2009), and the water cycle's evaporation, condensation and precipitation (Cardak, 2009). This is due to the abstract and complex nature of water's scientific concepts, the specific vocabulary that is new to students. Students also have limited prior knowledge. The results of the study concerning freshwater pollution showed that the students (aged 13-14) do not make the connection between the theoretical concepts and the practical context and therefore contextualization is a main factor in students' difficulty to understand theoretical concepts (Österlind & Halldén, 2007). Therefore, it is essential for educators to be aware of these misconceptions and other challenges in order to design water education programs to address and correct them (e.g., Levy & Moore Mensah, 2020).

Primary school students' drawings and written expressions included similarities between concepts of water, the water environment, and environmental health in various science education context (Havu-Nuutinen et al., 2011, 2018; Pozo-Muñoz et al., 2023). For example, students' perceptions included categories such as water in nature, clean water, the beauty of water, the enjoyment of water, and different water ecosystems (Havu-Nuutinen et al., 2011; Pozo-Muñoz et al., 2023). Students' perceptions included neutral, positive or negative attitudes towards water, such as the necessity of good water for health, the unhealthy consequences of poor hygiene as well as sustainable and unsustainable use of water during their everyday activities (Havu-Nuutinen et al., 2011, 2018; Pozo-Muñoz et al., 2023). Finnish primary school students' perceptions also emphasized the recreational aspect of water, such as skating, fishing and swimming (Havu-Nuutinen et al., 2011). Recreational activities on, in, and along freshwater have been shown to positively contribute to human well-being, but they can also disturb aquatic ecosystems (Venohr et al., 2018). Furthermore, engaging in recreational water activities can foster a sense of connection to the environment (Mulvaney et al., 2020).

Previous studies have shown that the solutions of present and future local, national and global water problems must be based on transdisciplinary perspectives (e.g., Jury & Vaux, 2005; Siew et al., 2016). Also, in the primary school science education context it is important to broaden water education beyond science classes (e.g., Havu-Nuutinen et al., 2018; Levy & Moore Mensah, 2020). Students could learn about the complex interconnectedness between water issues and sustainable development goals, such as reducing poverty or hindering gender equality (UNESCO, 2020). By incorporating transdisciplinary perspectives on water education, schools can create a more informed and engaged citizenship, capable of making positive changes towards sustainable water use (de Lázaro Torres, 2020). Real-life examples help students understand the impact of water issues also on the community level (e.g., Cosens et al., 2011; Forbes et al., 2018; Riskowski et al., 2009). This means SL at the primary school level is critical for effective participation in discussions and making informed decisions on issues related to science and technology, such as access to clean water and sanitation for all residents and promoting water conservation (e.g., Komarulzaman et al., 2019). Despite the impact of water-related decisions on both personal and societal levels, research in this domain at the primary school level remains relatively sparse. Hence, this study endeavors to shed light on primary school students' perceptions and socio-scientific reasoning (SSR) regarding water sources and usage at home and society. We aim to provide insights that can foster a deeper understanding about issues among primary school students.

Water education can be approached from various frameworks, for example the scientific inquiry approach, the science-based hydrological approach, the hydro-social cycle approach, the multi-pronged approach, and the socio-scientific approach. According to Harefa (2023), a scientific inquiry approach is an effective method for enhancing SL among primary school students (see also Osborne, 2023; Roberts & Bybee, 2014). This approach develops scientific process skills, encourages the cultivation of scientific attitudes and the ability to communicate scientific problems effectively (Harefa, 2023). Prasasti and Rahayu (2023) showed that there is a necessity to incorporate interesting and enjoyable activities into science learning for primary school students to further promote the development of SL. Nurturing curiosity can encourage lifelong learning and a passion for science (Cervetti et al., 2012; Miller & Miller, 2013; Osborne, 2023; Roberts & Bybee, 2014).

The science-based hydrological approach on water-related issues is more prominent than a hydro-social cycle approach (Khiri et al., 2023; Sammel, 2014; Sammel & Hartwig, 2019). The science-based hydrological approach interprets water primarily as a natural resource, emphasizing its chemical properties rather than social interactions and relationships (Sammel & Hartwig, 2019). The hydro-social cycle approach contends that water-related issues cannot be solely addressed through scientific and technical expertise, as social, political, economic, and cultural factors play crucial roles. This approach enables a comprehensive understanding of water issues, encompassing both local and global concerns (Linton & Budds, 2014). The hydro-social cycle approach included the importance of clean water for human health and wellbeing. According to Liu (2009) and Liu et al. (2014), primary school students have a favorable attitude towards water, perceiving it as a healthy and refreshing beverage. Collectively, these findings suggest that primary school students possess positive perceptions of water, considering it as a healthy and refreshing drink.

Iwasaki (2022) has showed that developing educational programs that encourage water-saving behaviors among young children requires a multi-pronged approach. In addition to incorporating visual prompts (water coils placed next to water taps) it is important to ensure active communication between the children, their teachers, and parents. Also, Davis (2005) demonstrated the efficacy of water conservation programs in kindergartens, highlighting that the habits developed in such programs were successfully transferred to children's homes (see also Duhn & Ritchie, 2014; Mackey, 2012; Vaealiki & Mackey, 2008). In their analysis of water-related topics in school curricula in Morocco, Khiri et al. (2023) recommend enhancing school actors' capacities, facilitating field trips, and improving accessibility of water information. They emphasize the need to enhance the capacities of school actors, such as teachers and administrators, to facilitate field trips for students and to improve the accessibility of water information. Khiri et al. (2023) also stress the importance of school-family cooperation in promoting responsible water consumption habits, raising awareness of water security challenges and encouraging sustainability. Additionally, they highlight the importance of educating students on their role as citizens in addressing water issues (Khiri et al., 2023).

The socio-scientific approach in water education refers to an educational framework that combines social and scientific perspectives to address water-related issues. It recognizes that water issues, such as water pollution, are not just a scientific or technical matter but also a social, cultural, economic, and political issue that requires interdisciplinary understanding and collaboration (e.g., Sadler, 2011; Sadler et al., 2007). For example, water pollution needs to be studied via relevant social systems (e.g., economical systems) and scientific systems (e.g., earth systems). SSR is key to helping students take informed positions around socio-scientific issues (SSIs) and it is an integral part of SL (vision II, III) and one of the key competencies (UNESCO, 2016). SSR comprises four competencies: recognizing the complexity of SSIs, multiple perspectives around SSIs, the need for ongoing inquiry around SSIs, and skepticism around different parties' claims made about SSIs (Romine et al., 2020). SSIs pose a considerable challenge for students due to the intricate nature of SSR required to make informed decisions about them (e.g., Ben-Horin et al., 2023). Ben-Horin et al. (2023) added the fifth dimension, coping with decision-making in SSIs in the networked society. According to Abrori et al. (2023), the breadth of SSR exhibited by elementary school students is notably rich and diverse. The fifth graders showed a multi-faceted understanding about societal issues, demonstrating their readiness to engage in SSR and the comic-based intervention efficiently nurtured students' reasoning abilities and navigating SSIs (Abrori et al., 2023).

The aim of this study was exploring Finnish primary school students' perceptions on water systems, including their SSR of where water comes from and where it goes. To achieve these, group conversations were used. This allowed for a more in-depth exploration of students' perceptions as well as providing a space for them to share their perceptions and reasoning with their peers. The research questions of this study are:

1. What do primary school students discuss when presenting statements in the context of water consumption?
2. What do primary school students discuss when presenting statements in the context of water purification?
3. What kind of SSR appears around water issues when presenting statements regarding water use and water purification?

MATERIALS & METHODS

This case study is part of a larger intervention study involving four rural primary schools in the Eastern part of Finland. A total of 108 third and fourth grade students (ages 9-11) participated in the study. The final number of participants with consent to be included in the research was 101 (48 girls and 53 boys). The intervention was enrolled as a part of the regular curriculum and students participated in it during their school lessons. The intervention was planned by a class teacher and three researchers in educational science in co-operation and piloted with two classes in autumn 2021. The intervention, which was carried out during January-May 2022, comprised a totally of 15, 45-minute lessons. It included two introduction lessons, eight lessons on water content, four lessons on nutrition content and one lesson to summarize the intervention. In this case study, we look specifically at lessons on water content. The class teachers participating in the intervention were trained on the principles and practical implementation of intervention research, the teaching content and pedagogical approach (3×45 minutes online). The teachers were responsible for teaching the lessons, but they had one-two research assistants to help.

During the lessons, the students' prior knowledge was reviewed, the topic of the class was discussed through an orientation video, the students worked on the research assignment in different ways, and their emotions during their work were measured. The students summarized their learning in their own research diary (worksheet provided by the project). In every science lesson, the students were encouraged to work collaboratively in small groups consisting of three or four individuals. The teacher carefully selected the group members to ensure a diverse mix of gender, ability, and motivation in the subject area. In this case study, we concentrate especially on recorded group conversations. In addition to group work, certain lessons also incorporated individual assignments as homework, such as discussions with parents, or home observation tasks. These tasks provided an opportunity for students to further explore and apply the concepts they had learned in lessons, while also encouraging independent thinking and self-reflection in their home environment.

The content (water and nutrition) to be taught in the intervention was based on national core curriculum of basic education (Finnish National Board of Education [FNBE], 2014). From grade 1-grade 6, science education in Finnish primary schools is a part of the 'environmental studies' subject group and it emphasizes pupils' prerequisites for taking care of their wellbeing and health, biology, chemistry, geography and physics. The aim of basic education must also be to impart general capabilities that promote interest and a positive attitude toward work and working life (FNBE, 2014). Therefore, Finnish schools are encouraged to develop partnerships within the local community, and they can decide for themselves what kind of partnership and activities they wish to develop. Thus, the intervention in this study is planned based on the SSI approach and environmental education (e.g., Sadler et al., 2007; Sadler, 2011).

Finnish national core curriculum for basic education is based on transversal competencies such as learning critical thinking skills and communication (FNBE, 2014). The curriculum also focuses on the use of knowledge in inquiry, life and living and society-related situations (FNBE, 2014). According to Lavonen (2021), the description of the core subject matter knowledge aims to integrate SL vision I (a conceptual approach) and SL vision II (a contextual approach) related to the development of science literacy. SL vision II concerns knowledge about science and focuses on public understanding of science, emphasizing applications of science in various personal, local and global contexts (Lavonen, 2021). SL vision III focuses especially on SSIs in science education (Lavonen, 2021). SSR such as working together, interacting with others for problem solving and making conclusions are transversal competences. Most of the assignment is based on SL vision I and vision II, but there are also assignments, which include the elements of SL vision III, for example in theme 2 when students create a demonstration sign about water consumption (**Table 1**).

Data Collection

This study adopted qualitative methodology aimed at obtaining a holistic understanding of the students' perceptions of water systems. The main data were collected through audio recordings of group conversations on tasks given in the science lessons. The teacher selected the participants, with group sizes ranging from three to five individuals. Additionally, the teacher played a role in specifying both the time and location of the conversations. The aim of this was that groups can be used to create a safe peer environment for primary school students. A conversation guide was shortly prepared before group conversations. Conversations were supported by statement cards about the circulation of domestic water and water consumption. The statement cards were in front of the students on the table, each student picked up one card in turn, read it out loud and then the group discussed the subject. Each conversation was recorded.

Ethical issues were considered during the water project (see Finnish National Board on Research Integrity TENK 4, 2023). Parents' consent was requested for pupils' participation in the study, and this was granted almost unanimously. We also received permission from the Review Board at the University of Eastern Finland. Pedagogical ethics were followed during the project. The pupils participated in the water project as part of their schoolwork. Students were allowed to practice using the tape recorders and teachers discussed with them why it is important for researchers to collect information. The researchers respected the dignity and autonomy of students, and the research did not cause damage or harm to participants.

Drawings and written expressions are used in many studies when studying primary school students' perceptions concerning water issues (Havu-Nuutinen et al., 2011, 2018; Pozo-Muñoz et al., 2023). In this study we used group conversation because previous studies have

Table 1. Description of water learning project

Lesson	School assignment	Activity concerning water
Introduction lessons (2×45 min.)	Prior knowledge	Individual writing assignment: Students' pre-conceptions about water (What do you want to know about water, how can you study water?)
Theme 1: Recreational use of water? (2×45 min.)	Prior knowledge	Group assignment & class discussion: Pantomime of different water use
	Orientation video	Different ways of using water
	Research assignment Homework	Exploring water-related attractions in Finland through digital map application (Google Earth)
	Research & argumentation assignment	An interview of a friend/relative about water hobbies Group discussion & argumentation: Best water-related hobby & the most environmentally friendly hobby
	Homework	Drawing & writing: How did you use water today?
Theme 2: Water treatment? (4×45 min.)	Prior knowledge	Individual assignment with cards: Where does the water come from & where does used water go?
	Orientation video	Introducing water purifying process
	Research assignment	Group assignments: Visiting water treatment plant (virtual glasses) Building of own water treatment plant (making hypothesis) Story and writing assignment of daily water use Creating interview questions for a "water expert" Whole class: Interviewing a "water expert" (online meeting)
	Research assignment	Group assignment Reporting findings from own water treatment plants
	Homework	Reading a science media text about concepts of surface water and groundwater and planning a demonstration sign
	Research assignment	Creating a demonstration sign about water consumption
	Argumentation assignment	Group discussions Why is it important to clean and save water?
	Homework	Studying the given water diagram of water uses and considering with parents how you use water at home
Theme 3: Natural water? (2×45 min.)	Prior knowledge	Individual assignment: Drawing & writing what causes natural water pollution
	Orientation video	Exploring natural waters
	Research assignment	Group assignments: Analysis of own water samples with foaming experiment and digital microscope (Easi-scope) Criss-cross of water concepts Card game: True or false (argumentation)
	Homework	Water filtration experiment

showed that groups can avoid some of the power imbalances between researchers and participants, for example, those between an adult and a child in a one-on-one interview (Shaw et al., 2011). Conversations have been used in many research projects with young people, for example to analyze their experience of controversial issues (e.g., Demant & Järvinen, 2006; Moran et al., 2012). Using conversations can help in understanding how primary school students perceive themselves and the world around them. By using conversations the researchers assume the leading role, and students are key informants and active social agents in their own lives (Swain et al., 2022). Conversations are also commonly used in social sciences and health-related research because they enable the collection of in-depth data providing more details of the phenomenon under study (Barbour, 2014; Swain et al., 2022).

Data Analysis

In order to reveal the main themes in data, content analysis (Krippendorff, 2018) was chosen for the data when analyzing students' perceptions. Orientation for the analysis was data-based content analysis, and the analysis was performed as a phenomenological process. The main analyzer (first writer) read the transcripts to formulate a tentative understanding and in subsequent reading attempted to confirm what had earlier been understood. In the first phase, the unit of content analysis was the claim made by the individual student. The claim may have contained one or more sentences. Group conversations were divided into four categories:

Table 2. Description of main categories

Category	Description of conversation category
Health	Conversation which addressed physical, mental, and social well-being, the absence of disease, adaptation to the environment by humans
Conservation	Conversation which addressed prevention of wasteful use of water resources, water protection, or restoration of the natural environment
Environment	Conversation which addressed conditions in which a person, animal, or plant lives
Household/everyday context	Conversation which addressed water related activities and experiences that constitute a person's normal existence happening or used every day

Table 3. Modified SOLO-taxonomy

Modified SOLO-taxonomy level	Description of quality of group conversation
Pre-structural & uni-structural	Conversation included only one viewpoint or contained incorrect information
Multi-structural level & relational level	Conversation included two reasons/viewpoints, students discussed significance of different reasons/viewpoints is relation to whole
Extended level	Conversation included generalized principles viewpoints

Table 4. Categories of primary school students' perceptions during group conversations connected to water consumption

Main aspect	Description of perceptions
Conservation aspect	
Future aspect	"Water is to be saved **for next year."**
Energy saving	"Water **costs** a lot. One drop will cost you. It's a lot of money."
Cost saving	"There is a lot of **energ**y in warm water."
Economy	"When you take water, that means using **money.**"
Limited water resources	"There are a lot of water issues going on in world. **In some countries things are not so good.**"
Solutions to save water in everyday context	"Do not waste water. **Do not turn on tap as soon as you wash** your teeth or take a shower."
Intrinsic value of water	"**Water is worth saving**."
Health aspect	
Existence value	"Water is very important. **Everything would be extinct**."
Contingent value	"You would all grow up to die. You cannot drink, people & **all living things need water.**"
Environmental aspect	
Environment protection & recycling possibility	"I think it is important to clean water so that it can **be recycled** & not wasted."
Drought	"World **would be a desert**. There'd be sand everywhere."
Destruction	"If water runs out, **we will die**."

health, conservation, environment, and everyday category (**Table 2**).

In the second phase the students' conversations were examined as a whole and claims of all the students were considered. Structure of observed learning outcome (SOLO)-taxonomy is used to describe the complexity of group conversations. According to Biggs and Collins (1982), SOLO-taxonomy is divided into five major levels:

(1) pre-structural,

(2) uni-structural,

(3) multi-structural,

(4) relational, and

(5) extended abstract.

In this study, we used only three major levels to describe the complexity of conversations, the pre-structural and uni-structural levels being combined as well as multi-structural and relational levels. This is line with the criteria of complexity and perspectives-taking of SSR. The students' conversations were quite brief and therefore the modified SOLO-taxonomy aims to offer a more tailored framework for the analysis and interpretation of the research findings. The classification criteria are shown in **Table 3**.

The data were analyzed in the context of a particular setting and perceived demands and did not represent any absolute "truths". Excerpts of focus group discussions are presented to confirm the categorization. This study was conducted in four school, which impacts the generalizability of the results. The results gained very similar and therefore the results may well be transferable to other school environments in Finland. During the data analysis process, the researchers co-operated on the coding system to aid the credibility and trustworthiness of the analysis (e.g., Elo et al., 2014).

RESULTS

Students' Perceptions of Water Consumption

When primary school students were asked about water consumption, their conversations included three

Table 5. Categories of primary school students' perceptions during group conversations connected to water purification

Main aspect	Description of perceptions
Health aspect	
Health problems	"You cannot drink water directly from lake, otherwise **you'll get sick**."
Harmful contaminants	"There are **bacteria and poisons** in river, it must be cleaned. People throw garbage, poop, & cans of energy drinks into water."
Essential element of survival	"There may be **corona, poison**, or some may swim & pee in it." "Let's take **stomach diseases** out, take those germs out." **"There's water inside of a human being. All substances contain water."**
Household aspect	
Cooking	"You can **cook** with clean water."
Shower & WC	"**WC** & **shower** will provide wastewater."
Drinking	"You cannot **drink** water because it's dirty. Sea water is salty & dirty."
A code of behavior	"**Do not put gum in sewer**."
Environmental aspect	
Cleaning of water requires	"**Cleaning of water requires a lot of manpower**."
Conversational aspect	
Water resources in other countries	"**No clean water** comes from water taps all over the world."

main aspects: conservation, health, and environmental (**Table 4**).

The students' perceptions included the conservation aspect of preserving water resources, emphasizing the need to protect and responsibly manage this precious natural asset. They also appreciated the conservation aspect related to cost and energy savings, acknowledging that efficient water use leads to reduced expenses and contributes to energy conservation. Additionally, the students highlighted the conservation aspect of finding solutions for water conservation in their everyday life, suggesting practical measures to minimize water usage and promote sustainability. They expressed an understanding of the intrinsic value of water, recognizing its importance for life, ecosystems, and the environment as a whole.

The health aspect was also addressed, with students acknowledging the significance of saving water for personal and community health (**Table 4**). Furthermore, the students discussed the environmental aspect of water conservation, emphasizing the protection of the environment and the potential for water recycling (**Table 4**). They also recognized the impact of drought on water availability, highlighting the environmental aspect of preserving water during periods of water scarcity.

The conservation aspect was the largest category having personal, societal, and global level reasons. Heath aspects related more to human needs and living environment. Meanwhile, the environmental aspect indicated the view of ecological sustainability as well as hydrological circulation.

Students' Perceptions of Water Purification

When primary school students were asked about water purification, their responses included four main aspects: health, household, environmental and conservation aspects (**Table 5**). Primary school students highlighted that it is essential to ensure that the water we consume is free from harmful contaminants and pathogens to maintain good health and stay hydrated. Students also emphasized the vital importance of water in maintaining good health, underscoring the need for individuals to make conscious efforts to consume a sufficient amount of clean water on a daily basis (**Table 5**).

The household or everyday context view included conversation about the safety and quality of drinking water, and the importance of using proper water treatment and purification methods before drinking it. Overall, the group conversation emphasized the significance of understanding the main idea of how to ensure access to clean and safe drinking water (**Table 5**).

In addition to health benefits, water purification also has significant environmental benefits. Cultivating water-saving habits and ensuring that we consume clean water can have a significant impact on water conservation efforts and on the environment as a whole. Students recognized that individual actions could play a significant role in preserving this fundamental resource, ensuring that it remains available for future generations. Through their conversations, they acknowledged that water is a fundamental element of survival, not only for individual health and wellbeing, but for the sustainability of ecosystems and the health of the planet as a whole (see **Table 5**).

There were no mentions of emergency situations, such as natural disasters or mechanical problems. Additionally, there was no discussion regarding the industrial or agricultural use of water, nor was there any information provided regarding the quality of the water, such as its taste or odor. Furthermore, no guidance was provided on how to effectively remove pollutants and chemicals from water.

Table 6. Examples of quality of conversation in context of socio-scientific reasoning

SOLO-taxonomy level	Description of conversation
Statement: There is no need to save water	
Pre- & uni-structural	Student 45: **Statement: There is no need to save water.** I'm sure you do not need it, but you can save it, but you cannot put it in a wallet (no other comments!).
Multi-structural & relational	Student 30: **Statement: There is no need to save water.** Student 31: False. Student 32: False. Student 33: False. Student 31: That's what you save because then you'll spend less money on it. Student 32: Yes, and then. Student 33: So and there is plenty for other people. Student 32: So, if you have a big family somewhere, then you have enough for all of them then.
Statement: Wastewater can be discharged directly into the lake	
Pre- & uni-structural	Student 52: **Statement: Wastewater can be discharged directly into the lake**. False. Because then the lake waters become contaminated.
Extended abstract	Student 40: **Statement: Wastewater can be discharged directly into the lake**. Well, I don't think so, because if you do, there might be garbage in it, and then, for example, some fish could die from it or something. Student 43: Large cities pollute waters. In Finland, at least large cities do not pollute water, but Moscow or other cities, for example. In Moscow they'll put that dirty water into the Baltic Sea.
Statement: Joensuu wastewater treatment plant is in Kuhasalo	
Pre- & uni-structural	Student 46: **Statement: Joensuu wastewater treatment plant is in Kuhasalo**. Well. Student 47: What? Huh.
Multi-structural & relational	Student 46: **Joensuu wastewater treatment plant is in Kuhasalo**. Student 48: Well, if it is in Kuhasalo, how would it be there? Student 49: Well, probably likely ... I do not even know where it is. Student 49: ... because otherwise the school would not ask such a difficult question. You would not if you weren't there if it wasn't there.
Statement: The waters of our lakes are clean enough to drink	
Pre- & uni-structural	Student 31: **Statement: The waters of our lakes are clean enough to drink.** Yes, they are, but why are you drinking it right out of the lake, what? Student 32: Well, what if the lake has been cleaned? Student 31: Then they are clean, but you do not start drinking from a lake.
Multi-structural & relational	Student 42: **Statement: The waters of our lakes are clean enough to drink**. This is false because there can be so many harmful things in the lakes. Student 43: You can still swim there. Student 44: This is false because there are fish in lake. Water is not necessarily suitable for drinking.
Extended abstract	Student 61: **Statement: The waters of our lakes are clean enough to drink.** Student 62: No. Student 63: No, but sometimes if I visit grandma's house and they live by the lake, then when I always jump from a platform into the lake. Student 64, I've drunk it sometimes. Student 63: ... so, sometimes I can have a mouthful of lake water, but it's pretty clean, isn't it? I guess it is. Student 65: My dad did make coffee with lake water once. Student 63: I guess it's clean because I did not get any corona virus from it.
Statement: The water supply plant is the same as the sewage treatment plant.	
Pre- & uni-structural	Student 40: **Statement: The water supply plant is the same as the sewage treatment plant**. Student 40: I do not know. Teacher: How are the others? Student 41: No, I suppose not. So not according to student x. I do not know what I'm talking about.
Multi-structural & relational	Student 33: **Statement: The water supply plant is the same as the sewage treatment plant** [whispering that cannot be understood]. Student 34: No because. Student 35: Tell me. Pupil 36: Well, a water well is not the same as a sewage treatment plant, because the water is taken from the lake in the water well. The sewage treatment plant has cleaned water before lake.

Quality of Conversations in Context of Socio-Scientific Reasoning

According to SOLO-taxonomy, students' SSR is classified on three levels:

(1) pre- and uni-structural level,

(2) multi-structural and relational level, and

(3) extended abstract level.

Pre- and uni-structural conversations included only one viewpoint or conversation including scientific misconceptions. For example, the students' group conversation addressed the idea that saving water is based on financial responsibility or saving money for the benefit of oneself. Pre- and uni-structural conversations were quite short and typically only one student gave an explanation, and other students did not continue the conversation. Some primary school students have misunderstandings about the connection between the water supply plant and wastewater treatment in their hometown, municipality or clean water reservoir. Multi-structural and relational conversation included almost two viewpoints. For example, it is essential to save water and use it efficiently to protect this valuable resource and ensure that it is available for future generations. The extended abstract viewpoint included conversations, which also addressed regions around the world that are experiencing water scarcity, where the demand for water exceeds the available supply. In such areas, water conservation is more critical to ensure that people have access to enough water for their basic needs (**Table 6**).

During conversations every statement did not achieve the extended abstract level, but all statements achieved the pre- and uni-structural level. It might be difficult to continue the conversation if it presupposes information, for example, the location of the water purification plant. Therefore, students sometimes present quite naïve conclusions. Statements like "The waters of our lakes are clean enough to drink" and "Wastewater can be discharged directly into the lake" allowed for a high level of abstraction. These statements might be near to the student's everyday life experiences, and it is possible to analyze these from multiple perspectives.

DISCUSSION

This study examined third and fourth graders' perceptions of water systems in the context of a science education project that was aimed at developing student SL. During their conversations, primary school students discussed water issues when presenting statements regarding water consumption or purification. Therefore, this study is also linked to students' SSR. Overall, the students' conversations showed awareness of multiple aspects associated with water issues. Primary school students addressed household, health, conservation, and environmental views in their conversations. Students addressed water systems especially at home scientifically (vision I), but also water issues as societal and environmental phenomena (vision II and vision III). Therefore, it is possible to say that this study contributes to today's science education via promotion of SL (e.g., Holbrook, 2010; Sjöström & Eilks, 2018) and understanding of the usefulness of scientific knowledge in life and society as well as fostering change in behavior at individual and societal levels. The students' perceptions demonstrated economic implications of water usage, including the cost of water.

Students' perceptions revealed the importance of water issues in the context of everyday life, especially domestic water conservation behaviors. The science education context in our case is slightly different from those in countries, where there is a serious concern about water availability (see Amahmid et al., 2019; Hussein, 2017). All schools located in the Eastern part of Finland rely on groundwater for their water supply system. Nevertheless, water issues are actual and important also in other parts of Finland and this provided the possibility to use local- and national-level examples of water resources, water use and water treatment systems. Some students have misconceptions or confusion about the differences between a water supply plant and a sewage treatment plant. This is not a surprising result because many previous studies have showed challenges with scientific water concepts and processes (e.g., Evagorou et al., 2009; Grotzer & Basa, 2003).

The water project is based on scientific inquiry and a socio-scientific approach due to our national core curriculum for basic education (FNBE, 2014). Our results respond to a general international need to discuss water-related issues such as argued by Koop et al. (2019) as well as UNESCO (2020). Our water education project also fit well with science education's and environmental education's challenges as mentioned by Covitt et al. (2009), Jorgenson et al. (2019) as well as Payne (2020). The understanding of water as an environmental and technological system is essential in helping primary school students make their future decisions concerning natural resources and everyday behavior (SL vision I, II).

Our results showed that the students focused on household water uses but not on industrial and agricultural water use. Also, according to UNESCO (2020), farming accounts for around 70% of water used in the world today and also contributes to water pollution from excess nutrients, pesticides and other pollutants. Therefore, to enhance water education in primary schools, it is essential to broaden education beyond the physical aspects of water to incorporate social, cultural, economic, and political dimensions of water use and management. As Levy and Moore Mensah (2020) and Linton and Budds (2014) suggested, a comprehensive approach will enable students to grasp the full spectrum of water usage and appreciate the regulatory and monitoring aspects of water usage. Then students will be well-equipped to make informed decisions regarding water usage and conservation, contributing to a more sustainable future (cf. Kaya et al., 2012; Smith et al., 2012). This is also in line with SL vision III because making and justifying everyday choices requires that the student understands the importance of science and technology also in the environment and society (cf. Sjöström & Eilks, 2018). Our results, as well as description of the water project, are broadening the water-related research area.

This study also supports the previous benefits of SSI-approaches in which the multidimensional and transdisciplinary view of water issues are included (cf. Havu-Nuutinen et al., 2018). Our findings indicated that some primary school students have problems connecting the water supply plant and wastewater treatment in their hometown, municipality or clean water reservoirs. Those results could be explained by misconceptions, which have been found in many previous studies concerning, for example groundwater (cf. Ben-Zvi Assaraf et al., 2012; Reinfried, 2006) and water systems (Cardak, 2009). Making and justifying everyday water consumption choices requires that the student understands the role of a municipal water supply and wastewater treatment also in their own environment and society. According to the results of this study, primary school students did not clearly highlight, for example, the special features of the importance of Finnish agriculture and industry, nor Finnish water legislation. According to Sjöström and Eilks (2018), SL vison III highlights also political views as well as agency views. But it is also obvious that during science education it is important to pay attention to SL vision I because students need basic scientific knowledge and be familiar with main concepts such as groundwater to understand different water systems (vs. Roberts, 2007).

Primary school students' perceptions included the importance of clean water for human health and wellbeing. This result is line with the hydro-social cycle approach (e.g., Linton & Budds, 2014). Health aspects are a link between science and students' everyday experiences (Liu et al., 2014). Therefore, incorporating the recreational aspect of water into educational programs could be a valuable approach to not only promote SL but also foster an appreciation for the environment and encourage environmental responsibility. By recognizing the importance of recreational water use and its potential impacts on ecosystems, educators can help students develop a holistic understanding of water issues and inspire them to become stewards of the environment.

Our findings revealed that the students' conversations were not confined to national or local-levels alone. Students drew attention to the issue of drought, which is not currently a major concern in Finland. Furthermore, the students adopted a global perspective when deliberating on the safety of drinking water and the adequacy of purification measures in Finland. According to UNESCO (2020), global aspects in water education are important because access to clean water is an essential factor in reducing poverty and it plays a crucial role in food production. Furthermore, clean water and sanitation are essential for human health. The lack of water and sanitation also disproportionately affects women and girls, hindering gender equality (UNESCO, 2020). In this study the students discussed that access to clean water is a fundamental human right that should be universally guaranteed and discussed the topic of water rights and equitable access for all individuals. The growing scarcity of water highlights the need for responsible consumption and production. To alleviate the situation, planning for sustainable cities and communities must incorporate water as a key component and citizens must have possibilities to participate.

CONCLUSIONS

The students' group conversations revealed perceptions, which varied from scientific to those concerning the meaning of water in the everyday context. Economic and environmental aspects of water were included such as pollution and water protection. Primary school students also described the use of water, the distribution of water-related problems in the world as well as water's meaning for life and for human beings. There is a need for SL (visions I-III) in the primary school context to help promote responsible water consumption habits and raise awareness about water security challenges. By educating students on their role as citizens in addressing water issues, we can inspire the next generation to become active participants in creating a more sustainable future.

This study has been carried out in authentic school contexts as part of normal schoolwork. This study highlights the importance of SL and awareness of concrete pedagogical challenges concerning water education at the primary school level. To some extent, the study results are limited from the viewpoint of a controlled study design, but on the other hand, this study has been conducted using group conversations from different primary schools that can be transferred to any school setting (e.g., Hennink et al., 2020; Taylor et al., 2015). In the future, it would be good to consider more cultural as well as social features, for example recreational use of water at the national and local levels (Havu-Nuutinen et al., 2011). The role of families should also be considered in the future, as shown by Khiri et al. (2023). Our study was done in a small city but there was still some confusion or uncertainty among the primary school students regarding the location of the wastewater treatment plant. It is interesting to see how difficult it is for children to understand the scale of wastewater treatment in large cities.

Research using conversation as a research method for studying water issues at the primary school level is scarce. While conversations can be a valuable research method (e.g., Demant & Järvinen, 2006; Moran et al., 2012) for exploring primary school students' knowledge, opinions, and attitudes on water issues, there are some potential problems associated with this method. Our experiences indicated that some students may dominate the conversation, while others may not contribute as much, leading to imbalanced group dynamics and biased findings. It is also possible that some students may feel pressure to conform to their peers' opinions, even if they disagree or do not fully understand the topic, leading to inaccurate or incomplete responses. Due to our experiences, for future studies we suggest having a facilitator for each group who moderates the conversation. At the beginning of the project we had the task of learning how to use the recording machine and how to fill in the research diary, etc. (see **Table 1**), but it is also important to put more emphasis on communication between the group members while also encouraging independent thinking. Further research should continue investigating SSR. SOLO-taxonomy revealed the level of group conversations, and it might be that group conversation levels contribute to existing knowledge. Therefore, it was important that the teaching material addressed water purification processes, for example using comic strip illustrations (cf. Abrori et al., 2023). There is an obvious need to encourage students to connect and synthesize water issues and think about alternative perspectives.

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